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Mr. Meade Stirland
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Dear Mr. Stirland,

This letter is in response to our phone conversation on May 27, 1981. You had asked me for more information regarding carbon-14 analysis of the groundwater from the Jackpile sandstone. I hope the following information helps.

The most common isotopes of carbon are C^{12}, C^{13}, and C^{14}, of which the first two are stable and the third, radioactive. C^{14} is formed in the upper atmosphere and has a half life of about 5700 years. Any material in the biosphere that takes up CO_2 will have a certain quantity of C^{14}. Once that material leaves this C^{14} reservoir, the C^{14} will decay without replenishment. Thus, by measuring the C^{14} content of a material removed from this reservoir, an 'age' of the material is derived.

The application to groundwater dating involves counting the C^{14} content of the bicarbonate ion (the common ion of carbon in most groundwaters). The major problem associated with this involves determining all the potential sources of carbon in groundwater. The primary reaction is with carbon dioxide and water:

$$CO_2 + H_2O = H_2CO_3 = H^+ + HCO_3^-$$

of which a certain portion of the carbon is C^{14}. Another reaction is:

$$CaCO_3 = Ca^{++} + CO_3^{=}.$$

There is also the decay of organic debris in the aquifer; for example:

$$SO_4^{=} + CH_4 + H^+ = HCO_3^- + H_2S + H_2O$$

Only the first reaction adds C^{14} to water so comparing the C^{14}--total carbon ratio would give an inaccurate age determination.

To overcome this problem, the ratio of C^{12} to C^{13} is used. Organic carbon is commonly depleted in C^{13}, whereas marine limestones are enriched in C^{13}. The ratio of C^{12} to C^{13} gives an estimate of the relative amounts of carbon from each of the above sources. Thus, a correction is applied, and this corrected C^{14}-C ratio is used to calculate the age of the groundwater.

A final problem in dating involves the actual in-situ generation of C^{14} through radioactive decay within the aquifer--this caused us considerable concern in our assessment of the method in this area. It has been demonstrated, and published, however, that C^{14} is an extremely minor decay product, and the possible maximum addition of less than 1% of C^{14} is less than any significance we would give to the result.

The value of this age determination for the Jackpile water is to assist us in determining some characteristics of the hydraulic system. We suspect that all water in the Jackpile reaches it interformationally, from higher stratigraphic units. A young carbon age for this water (compared to our calculated, 'darcian' age) would suggest that this is the case. An old age would cause us to reject this hypothesis, and choose another, such as leakage from the underlying Westwater Member. In essence, it is one more piece of data for us to assess the hydrogeologic situation.

The requirements for C^{14} analysis of groundwater is about four grams of carbon. In water from the Jackpile Mine (P-10 analysis) there is about 370 mg/l bicarbonate. Thus about 55 liters of water would have to be collected. The sampling procedure involves 1) running the pump until pH, temperature, and specific conductivity have stabilized; 2) filling a rinsed 60-liter bottle via a sampling tube running from inside the discharge pipe (or from the spigot) to the bottom of the bottle; in this way the bottle is filled from the bottom to overflowing and air contact is minimized; 3) the sample is raised to pH>11 with sodium hydroxide; the carbon is now all in the form of $CO_3^{=}$; 4) the carbon is precipitated through addition of barium sulfate and a flocculant; 5) after 12-24 hours the supernatant is decanted and the flocculant is stored in a smaller bottle. This is brought back to the lab for analysis.

The analytical procedure involves either acidifying the flocculant to release all carbon as CO_2 and measuring the C^{14} in a gas-proportional counter; or converting the carbon to lithium carbide and counting C^{14} through a liquid-

scintillation counter. Both techniques are available at the Laboratory of Isotope Geochemistry at the University of Arizona.

The problem of sampling undisturbed Jackpile water was one I had hoped to address in the field. This is why I was ambiguous about which well was to be sampled. I am not totally familiar with the mining area so I wanted to see the site and be able to select the well that was farthest from mining activities.

At this time I cannot say when I can return to the Laguna area. Project completion dates are approaching and most of my time is required in the office. Mid-July would probably be the soonest I could return for sampling. Perhaps I can call you at some later date.

I hope this has answered some of your questions. If you have more queries or need clarification, please call or write.

Sincerely yours,

John J. Ward

cc: Pat Wise, Pueblo of Laguna